S/N 10/612,658 **PATENT**

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applieant:	Miehael P. Galligan et al.	Examiner: Ngoe Yen M Nguyen
Serial No.:	10/612,658	Group Art Unit: 1754
Filed:	July 2, 2003	Doeket: 4576/4581A
Conf. No.:	5534	
Title:	Pliable Metal Catalyst Carriers, Conformable Catalyst Members Made Therefrom and Methods of Installing the Same	

DECLARATION UNDER 37 C.F.R. § 1.132

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir :

I, Miehael P. Galligan, hereby declare that :

1. I am a citizen of the United States residing in Cranford, New Jersey.

2. I reeeived my undergraduate degree in Bio-Chemical Seiences from West Virginia University in 1980 and an M.S. degree in Chemistry / Business Seiences from West Virginia University 1983. I have also received associate degrees in biological science and environmental engineering, and I received a B.S. in Chemistry from Kean University in 1986.

3. My research specialty is in the field of catalysts, particularly mixed-phase catalysts, including slurries of solids and liquids. My work in the field of catalysts began in 1987 when I was employed at Engelhard Corporation, now BASF Catalysts LLC, the assignee of the present invention. My work includes research and development of aircraft catalysts, automotive catalysts, diesel catalysts, and small engine and motorcycle catalyst, and in particular, the application of mixed-phase catalysts to metallic substrates.

4. I am a co-inventor on at least 20 patents worldwide, and I havc authored or co-authored several technical papers in the field of catalysts.

5. Exhibit A attached hereto is a conference paper presented in Pisa, Italy at a Society of Automotive Engineers Conference in July 2001, entitled "Flextube™ Catalyst Performance In 4-Stroke Motorcycle Exhaust Systems Is Demonstrated", which demonstrates unexpected results associated with the invention defined by the amended claims in the application rcferenced above.

6. In Exhibit A, conformable catalyst members as described and claimed in the patent

application refercnced above were tested and compared to rigid heat tubes for eatalytic activity when inserted in the exhaust pipe of a 4-stroke motorcyele engine. The performance of conformable catalyst members was compared to rigid heat tubes having similar dimensions and under similar conditions.

7. As diseussed on page 5 of Exhibit A, e 19-mm conformable catalyst members, referred to as Flextube™, unexpectedly had HC conversions from 5% to 15% greater, and CO conversions between 0% and 15% greater, than those of a 21-mm rigid tube. A 24-mm Flextube™ unexpectedly had HC conversions from 5% to 20% greater, and CO conversions between 10% and 20% greater, than those of a 27-mm rigid tube.

8. As discussed on page 9 of Exhibit A, a 24-mm OD Flextube™ unexpcctedly achieved higher CO conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340°C, the Flextube™ achieved 83% CO conversion and the rigid tube achieved about 70% CO conversion. The Flextube™ unexpectedly achieved higher CO conversions than the rigid tube under all steady-state conditions except the last condition. At this condition, the exhaust became rich, and the higher HC conversion of the Flextube™ rcsulted in higher CO make in the rich exhaust.

9. As discussed on page 9 of Exhibit A, in R40 engine testing, which involved using a 4-stroke, 80-cc motorbike to evaluate samples over the ECE R40 drive cyele, a 19-mm OD Flextube™ achieved HC and CO reductions of 63% and 47%, respectively. A 21-mm OD rigid heat tube achieved 38% HC reduction and 40% CO reduction. A 24-mm OD Flextube™ achieved 59% HC reduction and 32% CO reduction, and the 27-mm OD rigid heat tube achieved 44% HC reduction and 29% CO reduction.

10. In another set of tests, discussed at page a 19-mm OD x 260-mm L Flextube™ and a 21-mm OD x 260-mm L rigid tube were both catalyzed with 20/1 Pt/Rh. The Flextube™ was tested in a close-coupled position, with the inlet located 50 mm downstream of the engine exhaust port. Both the Flextube™ and the rigid tube were tested at a location where the inlet was 300 mm downstream of the engine exhaust port. The results for the conformable catalyst member Flextube™ were unexpectedly good, as the close-coupled Flextube™ achieved twice the HC conversion as the rigid tube located 300 mm downstream. The close-coupled Flextube™ achieved 50% more CO conversion than the rigid tube located 300 mm downstream. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, the HC conversion incrcased from 63% to 81%, and the CO conversion increased from 47% to 62%. While the Flextube™ is similar in configuration to the tubular member recited in claim 1 and its dependent claims, I expect that a catalyst member having the configuration as recitcd in claims 34 and 35 would produce similar results since they are bendable and able to be inserted into the curved or bent portion of an exhaust pipe and able to be placed in a closely coupled position to increase turbulcnt flow.

11. I have reviewed the Examiner's Answer mailed on July 13, 2007 and the references relied upon by the Examiner in rejecting the claims then pending in the application referenced above. None of the cited referenccs, alone or in combination, teaches or

suggests the claimed invention of the instant patent application.

12. Regarding United States Patent No. 4,455,281 (Ishida), this referenee does not teach or suggest a conformable or bendable catalyst member. More specifically, there is no teaching or suggcstion in Ishida of a catalyst member that can be bent or curved so that the catalyst member can be inserted into a bent or curved engine exhaust pipe. The Examiner's Answer cites column 3, lines 60-63 of Ishida to support the rejection that the catalyst members can be subjected to bending. It is important to note a distinction in what Ishida between the bare **metal plates 5** and **a catalyst unit 3**, which is a metal plate with a catalyst substance 11 on the metal plate. This distinction is important when reading Ishida because bending **a bare metal plate** without an intermetallic anchor laycr or a catalyst coating thereon, as discusscd at column 3, lines 60-63 of Ishida is not considered to bc novel or unobvious. What I do consider novel and unobvious is providing a conformable catalyst mcmber having an intermetallic anchor layer on a metal carrier that can be bent along its length and inserted into a curved or bent exhaust pipc, and retain a catalytic coating on the carrier member after the catalyst member has been bent. These features are not described or suggested in Ishida.

13. Ishida actually tcaches that it is undesirable to bend or deform the catalyst member. At column 2, lines 5-14, Ishida teaches of the undesirable falling off of catalytic substance when metal plates or wire meshcs containing catalytic substance are bent. Ishida further teaches (at column 4, lincs 47-52) that the that "the size and thickness of the **metal plate** is suitably selected depending on the dimensions of the apparatus for exhaust gas denitrification, the **amount of catalyst to be held by the metal plate**. The thickness is preferably thin, but **toughness of the mctal plate is required in order not to easily yield to deformation**." (emphasis added) It is important to note in this passage that Ishida emphasizes that Ishida is discussing a bare metal plate, and that no catalyst has yet been applied to the plate, based on thc underlined passage "amount of catalyst to be held by the metal plate." Furthermore, as a person skilled in thc art, a plate that is "tough" and that does "not easily yield to deformation" refers to a rigid plate and teaches away from the invention claimed in the application referenced above.

14. Regarding thc references rclied upon on page 14 of the Examiner's Answer to characterize "toughness" of metal plates, it is my opinion that cach of these citations is taken out of context and do not pertain the field of metal plates used for catalysts. Starting with Dean et al (2001/0006008), the passage citcd in the Examiner's Answer states:

> [0022] The plate material of the collector of the present invention is any that is sufficiently flexible. A particular embodiment of the present collector is elastically flexible, so that it will recover its own, basic shape without the need for any intervention. The elastically flexible material will allow the plate to bend to the shape of the surface against which it is used but which will not allow the collected hydrogen to diffuse through and so be lost before detection and measurement. Embodiments of the plate body are made of a metal, a metallized plastic, or a plastic/metal laminate. The dimensions—and specifically the thickness—of the plates are such as to afford it the desired flexibility. One embodiment of the plate of the present invention is stainless steel, being particularly tough and sufficiently flexible to be suitable. Other embodiments of the plate of the present invention are made of plastic.

This passage, from a patent related to a plate for a hydrogen collector device, merely states that plates must be of a thiekness (i.e. sufficiently thin) so that they ean be flexible and be bent. This paragraph teaches the opposite of Ishida, which requires the plates to be sufficient thick so they eannot be bent.

15. Regarding Tormala et al. (6,221,075), related to an implantable bone fixation plate, the passage cited in the Examiner's answer is reproduced below:

> The main advantage of metallic plates (like titanium, stainless steel and cobalt chrome molybdenum plates), is that they are strong, tough and ductile so that they can be deformed or shaped (e.g., bended) at room temperature in the operation room, either by hand or with special instruments, to a form corresponding to the surface topography of bone to be fixed. In this way, the plate can be fixed flush on the bone surface to which the plate is applied.

This passage teaehes that metallic plates can be tough and ductile. Toughness and flexibility (or deformation) of a metal plate should not be confused. Toughness refers to the resistance to fracture of a material when stressed. Toughness is defined as the amount of energy that a material can absorb before rupturing, and can be found by taking the area (i.e., by taking the integral) underneath the stress-strain eurve. It is important to note that ductility is the mechanical property of being capable of sustaining large plastie deformations due to tensile stress without fracture (in metals, sueh as being drawn into a wire). Ductility is eharacterized by the material flowing under shear stress. It is contrasted with brittleness. Therefore, when the passage quoted above says that a material is tough and ductile, this does not take into aceount the thickness of the metal plate and its flexibility or deformation due to bending.

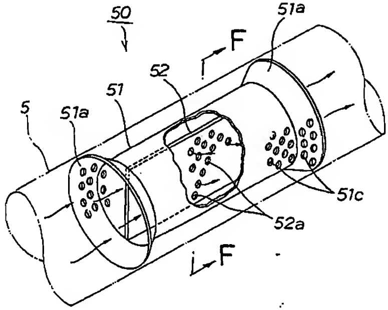
16. Regarding Grothues-Spork et al. (5,713,906), which relates to a prosthesis ehisel tip, the passage cited in the Examiner's Answer states:

> According to a preferred embodiment of the invention the chisel blade is made of a flexible flat strip of tough, resilient material, for instance of a flat strip of resilient stainless steel. In order to achieve an optimal fit with respect to the shaft surface of the endoprosthesis to be removed, the flat strip may have a bend or wave contour perpendicular to its longitudinal extension. In this case, the chisel blade may consist of a shape memory alloy, especially a nickel-titanium alloy or of a resilient synthetic material. In order to ensure the necessary flexibility, the chisel blade has a thickness of 0.2 to 0.6 mm. Chisel blades having different thicknesses

This passage makes the point that the chisel tip should be tough (i.e. resistant to fracture when stressed), but also sufficiently thin (0.2 to 0.6 mm) to remain flexible. It is submitted that at a certain thickness, the chisel tip would remain tough, but it would no longer be flexible, meaning that it would be able to be bent or deformed by applying a bending stress. Ishida refers to this concept that a plate should be tough and thick enough to not yield to deformation, which teaches away from my claimed invention.

17. Regarding EP0831211, this reference does not teach or suggest a corrugated tubular catalyst member that can be bent along its length so that it can be placed in a curved or bent exhaust pipe of an engine. In particular, I have reviewed Figures 16A and 16B and 16D and the text accompanying these Figures, which are relied upon in the Examiner's Answer as allegedly teaching a flexible catalyst member. The text of EP0831211 at column 13, lines 10-24 states that the exhaust purifier 50 in Figure 16B, which the Examiner's Answer (at page 16, lines 12-14) maintains is conformable, is not conformable or bendable along its length. Column 13, lines 14-17 states that the central exhaust purifier is constructed in the same manner as the downstream exhaust purifier 50 of Figure 12. The exhaust purifier in Figure 16A is also the same as the purifier shown in Figure 12 (see column 13 lines 7-9). A study of the purifier of Figure 12 shows that the purifier 50 is a <u>straight</u> unit containing a first catalytic bearing member 51 and a second catalytic metal bearing member 52, which is a straight plate. Figure 12 is reproduced below:

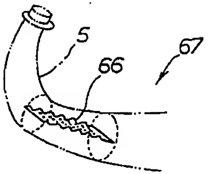
FIG. 12



As is clear from the reproduetion of Figurc 12, the exhaust purifier 50 is not at all conformable or bendable. It is a rigid cylindrical member housing a rigid straight plate, similar to the rigid tubes tested in Exhibit A and that had properties inferior to the conformable eatalyst members. In Figures 16A and 16B relied upon in the Examiner's Answer, the exhaust purifier 50 is arguably shown as slightly curved, but it is submitted this may be due to a distortion of element 50 in the drawing. To the extent it is maintained that the exhaust purifier 50 is shown as curved, this does not teach or suggest a conformable or bendable eatalyst member that can be inscrted into a bent or curved exhaust pipe and in which catalytie coating remains intact when the carrier is curved or bent along its length.

18. Regarding the strueture shown in Figure 16D, which is reprodueed below,

FIG. 16D



element 66 is described as a flat, porous corrugated steel sheet. There is no teaching or suggestion in the text associated with Figure 16D (namely column 13, lines 25-38) that the sheet 66 is bendable or will retain coating when inserted into a curved or bent exhaust pipe and bent along its length. It is important to note that the sheet 66 in Figure 16D is shown in a flat configuration, and the leading end of the sheet is placed at the curved portion of the exhaust pipe 5, and not inserted into the curved portion. This suggests that the sheet 66 may not be of an appropriate thickness to be bent and is not flexible. It is also important to note that a sheet of metal can be corrugated, yet it may not be flexible. For example, a sheet of corrugated steel used in the construction of industrial buildings has corrugations, but it is not easily bent or deformed. The invention claimed in my patent application, however, requires a catalyst member that is bendable or conformable and that retains the catalytic coating on the carrier when the carrier is bent or curved. This is not taught or suggested by EP0831211.

19. United States Patent Number 4,798,770 (Donomoto) and Draghi (6,042,879) are cited in the Examiner's Answer at page 7, and these are relied upon for the teaching of an anchor layer comprising nickel and aluminum. Neither Donomoto nor Draghi, however, teaches providing a conformable or bendable catalyst member as claimed in my patent application.

20. I have reviewed United States Patent Numbers 5,204,302 (Gorynin) and 5,204,302 (Rondeau), which are used together with EP0831211 and Ishida to reject claims 1-3, 5-6, and 30-36 on pages 8-12 of the Examiner's Answer. It is acknowledged that Gorynin teaches at column 9, lines 64-57, rolling a corrugated catalyst strip into a cylinder. Gorynin is discussed in my specification at page 2 lines 17 to page 3 line 6. Gorynin does not teach or suggest providing a catalyst member that is bendable along its length and that can be inserted into a curved or bent exhaust pipe and retain the catalytic coating layer. Rondeau is not relied up for teaching bendable catalyst members, and as discussed above, EP0831211 and Ishida fail to teach catalyst members that are bendable along their length and retain catalytic coating.

21. In summary, none of the references cited in the Examiner's Answer either alone or together teach or suggest all of the limitations of my claimed invention, namely a bendable carrier member that can be bent along its length and retain catalytic coating on

the carrier when the catalyst member is bent or curved to fit into a bent or curved exhaust pipe. Furthermore, conformable catalyst members as defined by my presently claimed invention performed unexpeetedly better than rigid catalyst members when inserted into exhaust pipes of a motorcycle in the removal of noxious components of the exhaust gas.

22. I hereby deelare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patents that may issue thereon.

IN WITNESS WHEREOF, I have executed this instrument on the date indicated below.

10-29-07
Date

Michael P. Galligan
Michael P. Galligan

EXHIBIT A

2001-01-1823

Flextube™ Catalyst Performance In 4-Stroke Motorcycle Exhaust Systems Is Demonstrated

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Abstract

An analysis of 4-stroke motorcycle emission systems indicates that a heat tube has the potential for meeting the regulatory standards if the location in the exhaust pipe matches the specific operating temperature requirements of the device. The location of a heat tube is determined by the diameter and shape of the exhaust pipe. Since the exhaust flowrate and temperature across the catalytic device determine its effectiveness, it is suggested that a flexible catalyzed tube, that could be placed anywhere in the exhaust, would have a greater potential than a rigid heat tube for solving a wide range of emission application needs. To maximize the benefit from such a simple cost effective device, the application of the "flex-tube catalyst" was studied over a wide range of conditions.

A test matrix that used high and low levels of Pt/Rh ratio and tube diameter was used to study "flex-tube catalyst" performance in 4-stroke motorcycle exhaust systems. Engine variables include inlet temperature, AFR, exhaust flow and backpressure. Catalyst variables that were probed included tube diameter, precious metal ratio, and rigid or Flextube™ design. Data will be presented to show the benefits of such a device in various configurations. Performance is assessed by comparing the conversion of pollutants at various temperatures and flowrates.

Introduction

The emission regulations for both 2-stroke and 4-stroke 2-wheelers are being tightened worldwide .[1] There are some significant differences in the emissions between the 2-stroke and 4-stroke engines. The 2-stroke have much higher HC emissions, and generally have lower exhaust-gas temperatures. Both 2-stroke and 4-stroke can have high CO emissions, especially if the engines are run rich.[2]

For a 4-stroke motorcycle, the higher exhaust-gas temperatures and the lower HC emissions present an opportunity to employ novel substrates for the catalytic oxidation of HC and CO. A current practice is to install a catalyzed rigid tube in the exhaust pipe between the engine and the muffler. This paper discusses experimental results to install a catalyzed flexible tube into the exhaust pipe. Figure 1 shows typical Flextube™ and rigid tube samples. Flexible tubes have the advantage of conforming to the bends in the exhaust pipe close to the engine. This allows for more rapid lightoff of the catalyst since temperatures are hotter closer to the engine. It also positions the catalyst directly along the wall of the bend, which is where the gases will sweep as they turn through the bend. This positioning, along with the corrugations of the Flextube™, enhance mass transfer in a region of the exhaust where the gases have sufficient thermal energy to take advantage of the improved mass transfer.

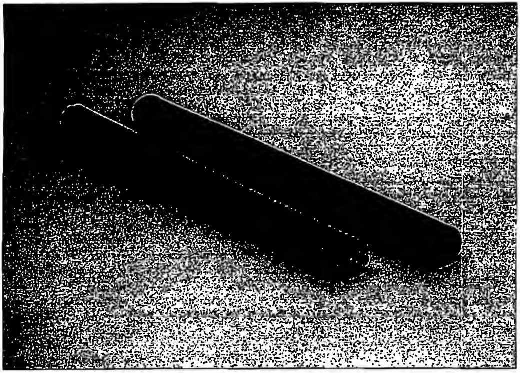

Figure 1
Typical Flextube™ and Rigid Heat Tubes

Experiments

Bench Engine Evaluation

Steady-state evaluations were performed using a 125-cc, 4-stroke motorcycle engine. The engine was coupled to a dynamometer for power absorption and load control. The engine was operated with a computer-based control and data acquisition system. The engine was instrumented to measure inlet and exit temperatures for the Flextube™, static pressure at the engine exhaust, throttle position, engine speed and load. In addition, an exhaust gas sample was taken downstream of the tubes. The sample was analyzed for CO, CO2, HC, O2, NOx, and SO2.

The engine's exhaust system was modified to facilitate installation of samples using a Flextube™ holder that was specifically fabricated and installed to study the devices. The Flextube™ samples were held in place by three machine screws evenly spaced around the perimeter of the sample at the inlet and exit ends. Each sample was installed with its inlet face at the same position in the exhaust system. The inlet face of each sample was 20 cm downstream from the engine exhaust port. The gas-stream temperature was measured 0.6 cm upstream of the tube inlet and 2.5 cm downstream of its exit.

For each steady-state condition, the engine was controlled to a constant speed and throttle setting for a period of five minutes. Temperatures, pressures and gas emissions are recorded once per second. Values for the final 30 seconds of the period are averaged and reported. Tube inlet temperatures ranged from about 350C at idle to about 725C at a throttle setting of 65%. The exhaust AFR was controlled by the engine, and ranged from a high of about 17.5 at idle to a low of 13 at 65% throttle setting.

Vehicle Evaluation

A 4-stroke, 80-cc motorbike was used to evaluate samples over the ECE R40 drive cycle. The bike's exhaust system was modified to allow easy installation of Flextubes™. A 30-cm length of stainless steel tubing with flanges on each end was added to the exhaust system between the engine exhaust and the muffler inlet. The tube inlet was positioned 30 cm downstream from the engine exhaust port. Thermocouple housings were located 1.2 cm from the engine exhaust port, and 5 cm from the inlet and exit faces of the tube.
The 19-mm OD Flextube™ and the 21-mm OD rigid tubes were tested in a 22-mm ID tube. The 24-mm OD Flextube™ and the 27-mm OD rigid tube were tested in a 34-mm ID tube.

All samples were tested twice, and the results were averaged. If the HC and CO2 mass emissions did not agree within ten percent, the test was repeated. A blank 19-mm OD x 260-mm L Flextube™ was tested in each tube holder to provide a baseline for the calculation of HC and CO conversions.

Design of Experiments

The catalyst technology used is Engelhard's MC20B technology. It is based upon patented segregated washcoat technology which permits optimum dispersion and distribution of the precious metals to maximize their performance.[3]
In order to measure the effectiveness of Flextubes™ and rigid tubes, the tube diameter and the Pt/Rh ratio were each varied at two levels. The length of all samples was held at 260 mm.

Table 1
Values of Flextube™ Design Parameters

	High	Low
Pt/Rh ratio	20/1	5/1
Tube inner diameter (mm)	14	15.5
Tube outer diameter (mm)	19	24

Table 2
Values of Rigid Tube Design Parameters

	High	Low
Pt/Rh ratio	20/1	5/1
Tube inner diameter (mm)	19	24
Tube outer diameter (mm)	21	27

Discussion and Results

Bench Engine Testing

Flextubes™ vs Rigid Tubes

All samples were evaluated for HC and CO conversion under steady-state conditions on an engine dynamometer. The results show that the Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions.

The following four figures highlight the performance differences between the Flextubes™ and rigid tubes. The performance data of the smaller diameter Flextube™ and rigid tubes are charted together, as are the data for the larger diameter Flextube™ and rigid tube. The HC and CO conversions for all of the samples were measured at inlet temperatures ranging from 350C to 750C. Figures 2a and 3a show the HC and CO

conversion, respectively, for the 19-mm OD Flextube™ and the 21-mm OD rigid tube. Figures 2b and 3b show the HC and CO conversion, respectively, 24-mm OD Flextube™ and the 27-mm OD rigid tube.

Steady-state bench engine testing showed that the Flextubes™ achieved higher HC and CO conversion than did rigid tubes of similar dimensions. The 19-mm Flextube™ had HC conversions from 5% to 15% greater, and CO conversions between 0% and 15% greater, than those of the 21-mm rigid tube. The 24-mm Flextube™ had HC conversions from 5% to 20% greater, and CO conversions between 10% and 20% greater, than those of the the 27-mm rigid tube.

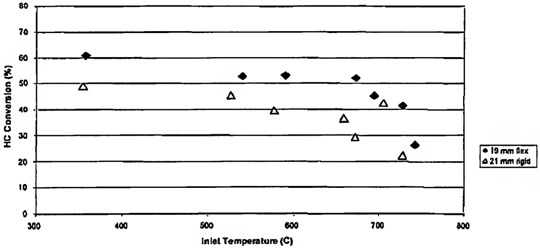

Figure 2a: Flextubes Achieve Higher HC Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

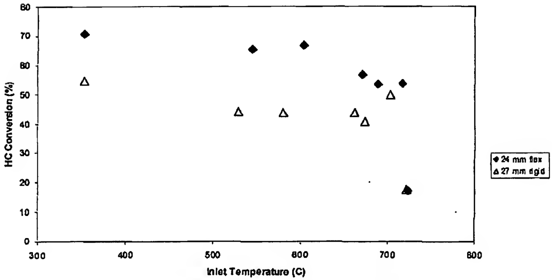

Figure 2b: Flextubes Achieve Higher HC Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

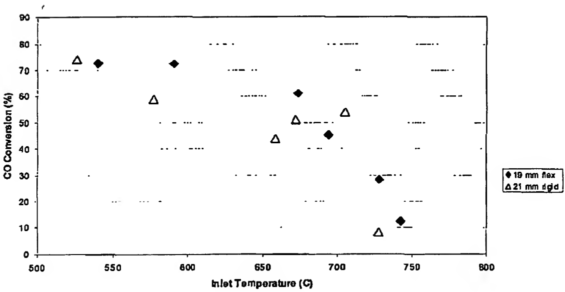

Figure 3a: Flextubes Achieve Higher CO Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

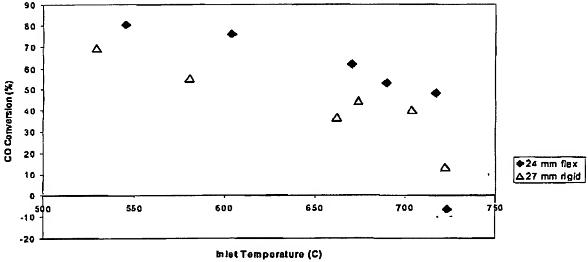

Figure 3b: Flextubes Achieve Higher CO Conversion than Rigid Tubes
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

Effect of Flextube™ Diameter

Bench engine testing showed that both HC and CO conversion were improved by using a larger-diameter Flextube™. As diameter increases, total catalyst surface area increases. The 24-mm OD Flextube™ generally achieved about 10% more HC and CO conversion than the 19-mm OD Flextube™. Figure 4a shows the improvement in HC conversion for the 24-mm OD Flextube™. Generally, the 24-mm OD Flextube™ achieved HC conversions that were between 5% and 13% higher than those of the 19-mm OD Flextube™. Figure 4b shows the improvement in CO conversion for the 24-mm OD Flextube™. Generally, the 24-mm OD Flextube™ achieved CO conversions that ranged between 0% and 20% greater than those of the 19-mm OD Flextube™. In Figure 4b, the highest-temperature set of datapoints show the 19-mm OD Flextube™ with 12% CO conversion, and the 24-mm OD Flextube™ with –6% CO conversion. This is because the engine exhaust was rich at this point, and the higher HC conversion of the 24-mm OD Flextube™ resulted in higher CO make under the rich conditions.

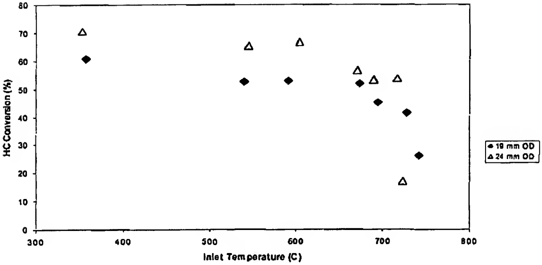

Figure 4a: Larger Diameter Flextubes Achieve Higher HC Conversion
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

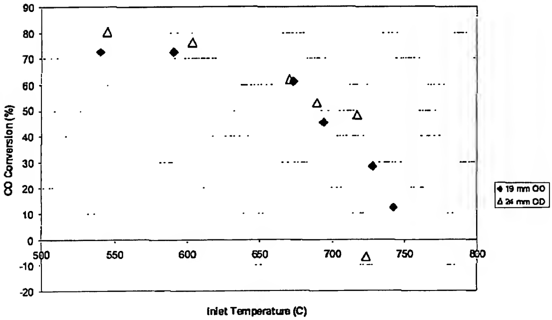

Figure 4b: Larger Diameter Flextubes Achieve Higher CO Conversion
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

Effect of Pt/Rh Ratio

The effect of Pt/Rh ratio was measured on the bench engine. Flextubes™ were catalyzed with MC20B catalyst technology, using either a Pt/Rh ratio of either 5/1 or 20/1. Steady-state tests showed that the 20/1 ratio performed as well as the 5/1 ratio for HC conversion. Figures 5a and 5b show the HC conversion of the 19-mm OD Flextube™, and the 24-mm OD Flextube™, respectively, with Pt/Rh ratios of 5/1 and 20/1.

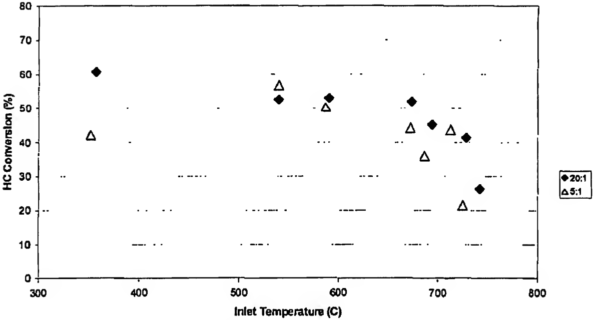

Figure 5a: 20/1 Pt/Rh Flextube Achieves HC Conversion Equal to 5/1 Pt/Rh Flextube MC20B on 19-mm OD x 260-mm L Flextubes

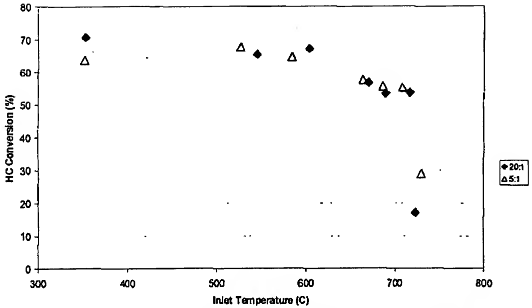

Figure 5b: 20/1 Pt/Rh Flextube Achieves HC Conversion Equal to 5/1 Pt/Rh Flextube MC20B on 24-mm OD x 260-mm L Flextubes

The final set of steady-state engine bench tests was a comparison between a 20/1 Pt/Rh 24-mm OD Flextube™ and a 5/1 Pt/Rh 27-mm OD rigid tube. Figures 6a and 6b show the HC and CO conversions, respectively, of the 24-mm OD Flextube™ coated with 20/1 Pt/Rh and the 27-mm OD rigid tube coated with 5/1 Pt/Rh. The 24-mm OD Flextube™ achieved significantly higher HC conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340C, the Flextube™ achieved 70% HC conversion and the rigid tube achieved about 20% HC conversion. The Flextube™ achieved about 20% higher HC conversion than the rigid tube until the last two steady-state conditions. These final steady-state conditions, obtained at 35% and 45% of full throttle, may represent a space velocity limitation of tubes of these dimensions.

The 24-mm OD Flextube™ achieved higher CO conversions than the 27-mm OD rigid tube. At the lowest inlet temperature of about 340C, the Flextube™ achieved 83% CO conversion and the rigid tube achieved about 70% CO conversion. The Flextube™ achieved higher CO conversions than the rigid tube under all steady-state conditions except the last condition. At this condition, the exhaust became rich, and the higher HC conversion of the Flextube™ resulted in higher CO make in the rich exhaust.

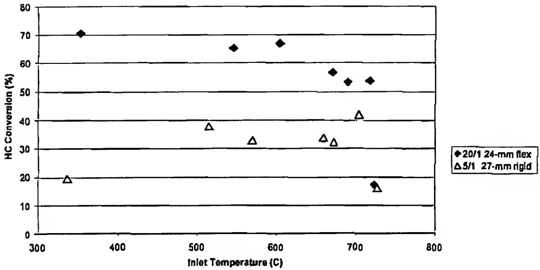

Figure 6a: 20/1 Pt/Rh Flextube Outperforms 5/1 Pt/Rh Rigid Tube
Steady-State HC Conversion on 125-cc 4-S Engine
MC20B Catalyst on 260-mm L Tubes

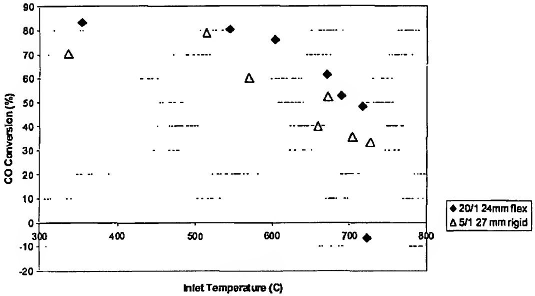

Figure 6b: 20/1 Pt/Rh Flextube Outperforms 5/1 Pt/Rh Rigid Tube
Steady-State CO Conversion on 125-cc 4-S Engine
MC20B Catalyst on 260-mm L Tubes

ECE R40 Results

All samples were tested twice using the ECE R40 drive cycle. The 19-mm OD Flextubes™ and the 21-mm OD rigid tubes were tested in a 22-mm ID tube. The 24-mm OD Flextube™ and the 27-mm OD rigid tube were tested in a 34-mm ID tube. ECE R40 testing shows that the Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions.

Effect of Pt/Rh Ratio

The effect of Pt/Rh ratio was measured on the 4-s vehicle. Flextubes™ were catalyzed with MC20B catalyst technology, using either a Pt/Rh ratio of either 5/1 or 20/1. In the R40 vehicle tests, the 20/1-ratio Flextubes™ achieved HC and CO conversions that were about 5% less than those of the 5/1-ratio Flextube™. Figure 7 shows the HC and CO conversions of the 19-mm OD Flextubes™ catalyzed with Pt/Rh ratios of 5/1 and 20/1.

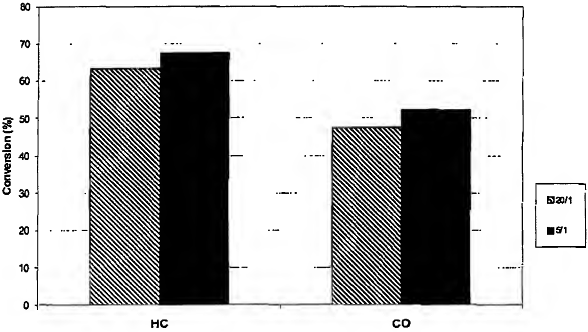

Figure 7: 20/1 & 5/1 Pt/Rh Flextubes Achieve Similar HC & CO Conversions in ECE R40 Test 19-mm OD x 260-mm L Flextubes with MC20B Catalyst

Effect of Gap Distance

The effect of the gap distance between the OD of the Flextube™ and the ID of the exhaust pipe was noted. The vehicle was run over the R40 cycle using the 20/1 Pt/Rh 19-mm OD Flextube™. One set of tests had the Flextube™ in the 22-mm ID exhaust pipe holder, and one set of tests had the Flextube™ in the 34-mm ID exhaust pipe holder. The emissions data showed that the higher conversions were achieved when the gap distance was about 1.5 mm.

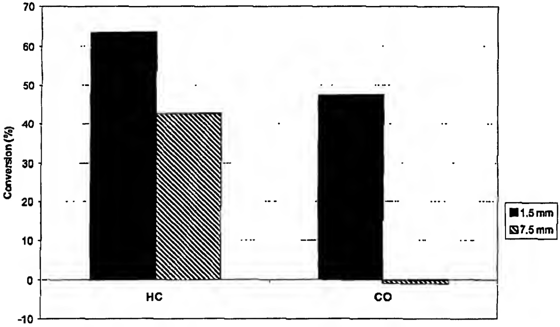

Figure 8: The 1.5-mm Gap Between Flextube and Exhaust Pipe Yields Higher HC & CO Conversion than the 7.5-mm Gap 20/1 Pt/Rh MC20B Catalyst on 19-mm OD x 260-m L Flextube

Flextube™ vs Rigid R40 Tests

The vehicle R40 testing showed that a Flextube™ achieved higher HC and CO conversion than a rigid tube of similar dimensions. Figures 9a and 9b compare the HC and CO conversions between a Flextube™ and a rigid tube of similar diameters. Figure 9a shows the small-OD tube data, and Figure 9b shows the large-OD tube data.

In the R40 testing, the 19-mm OD Flextube™ achieved HC and CO reductions of 63% and 47%, respectively. The 21-mm OD rigid heat tube achieved 38% HC reduction and 40% CO reduction. The 24-mm OD Flextube™ achieved 59% HC reduction and 32% CO reduction, and the 27-mm OD rigid heat tube achieved 44% HC reduction and 29% CO reduction.

The differences between the Flextube™ and rigid tube HC conversions were larger than the differences in CO conversions. This is probably due to limitations of O2 availability.

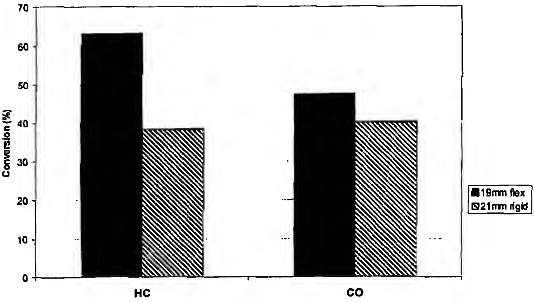

**Figure 9a: Small-Diameter Flextube Achieves Higher HC & CO Conversion than Rigid Tube in ECE R40 Testing
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes**

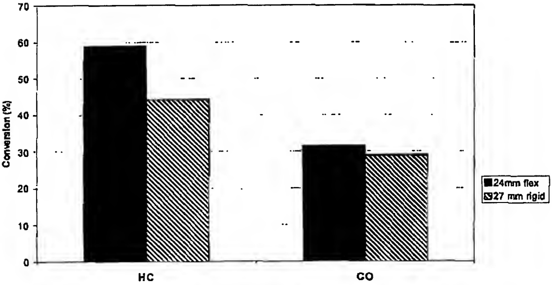

**Figure 9b: Large Diameter Flextube Achieves Higher HC & CO Conversion than Rigid Tube in ECE R40 Testing
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes**

Effect of a Close-Coupled Flextube™

A 19-mm OD x 260-mm L Flextube™ and a 21-mm OD x 260-mm L rigid tube were both catalyzed with 20/1 Pt/Rh MC20B catalyst technology. The Flextube™ was tested in a close-coupled position, with the inlet located 50 mm downstream of the engine exhaust port. Both the Flextube™ and the rigid tube were tested at a location where the inlet was 300 mm downstream of the engine exhaust port. Figure 10 is a schematic drawing of where the Flextube™ was positioned. Figures 11a & b show the results of these tests. The close-coupled Flextube™ achieved twice the HC conversion as the rigid tube located 300 mm downstream. The close-coupled Flextube™ achieved 50% more CO conversion than the rigid tube located 300 mm downstream. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, the HC conversion increased from 63% to 81%, and the CO conversion increased from 47% to 62%. These tests demonstrate that the Flextube™ is able to deliver more emission reduction if it is located closer to the engine exhaust. In a close-coupled position the Flextube™ can take full advantage of the turbulent flow and higher temperature.

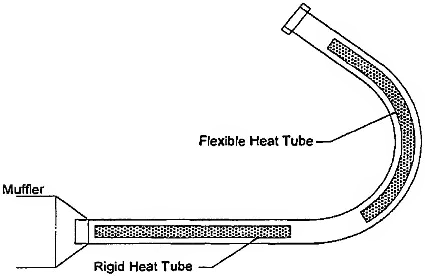

Figure 10
Schematic of Close-coupled Flextube™

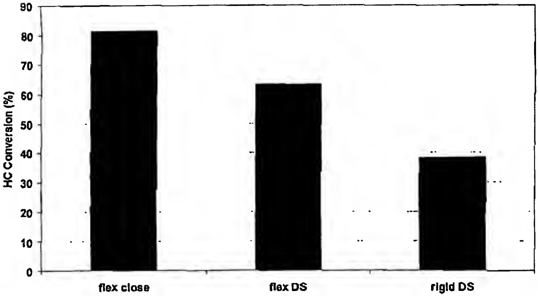

Fig 11a: Close-Coupled Flextube Achieves 100% more HC Conversion than a Rigid Tube Located 300 mm Downstream
20/1 Pt/Rh MC20B Catalyst Technology on 260-mm L Tubes

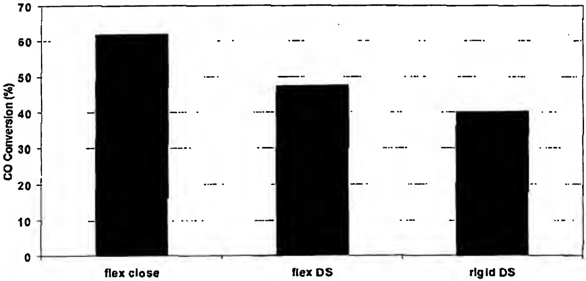

Fig 11b: Close-Coupled Flextube Achieves 50% more CO Conversion than a Rigid Tube Located 300 mm Downstream
20/1 Pt/Rh MC20B Catalyst on 260-mm L Tubes

Conclusions

The ECE R40 bike results show the benefits of utilizing a Flextube™ in a close-coupled position. In comparison with a rigid tube located 300 mm downstream, the close-coupled Flextube™ achieved 50% more CO conversion and 100% more HC conversion. Tests were also run to measure the effect of close-coupling on the Flextube™ itself. When the Flextube™ was moved from 300 mm downstream to 50 mm downstream, it achieved 33% more CO conversion and 25% more HC conversion.
The ECE R40 bike results and the steady-state engine testing both demonstrate that Flextubes™ achieve higher HC and CO conversions than rigid tubes of similar dimensions. In the R40 tests, Flextubes™ achieved between 15% and 25% higher HC conversion than the rigid tubes and between 3 and 7% more CO conversion than the rigid tubes.

Flextubes™ achieve higher HC and CO conversion by providing improved mass transfer. In the close-coupled position, they also take advantage of better chemical kinetics by being located in a position where the exhaust gases are hotter. This is especially important for drive cycles that do not allow for adequate warm-up of the exhaust system.

References

[1] AECC (Association for Emission Control by Catalyst), "Overview of Global Emission Standards for Two- and Three-Wheeled Vehicles", Brussels, Belgium, 9 November 2000

[2] J.C Dettling, M. Galligan, M. Larkin, J. Adomaitis, "Emission Control Strategies for 2- and 4-Stroke Motorcycles in India", SAE 2000-01-0002

[3] H.S. Hwang, J.C. Dettling, J.J. Mooney, "Catalytic Converter Development for Motorcycle Emission Control", SETC '97 SAE 972143